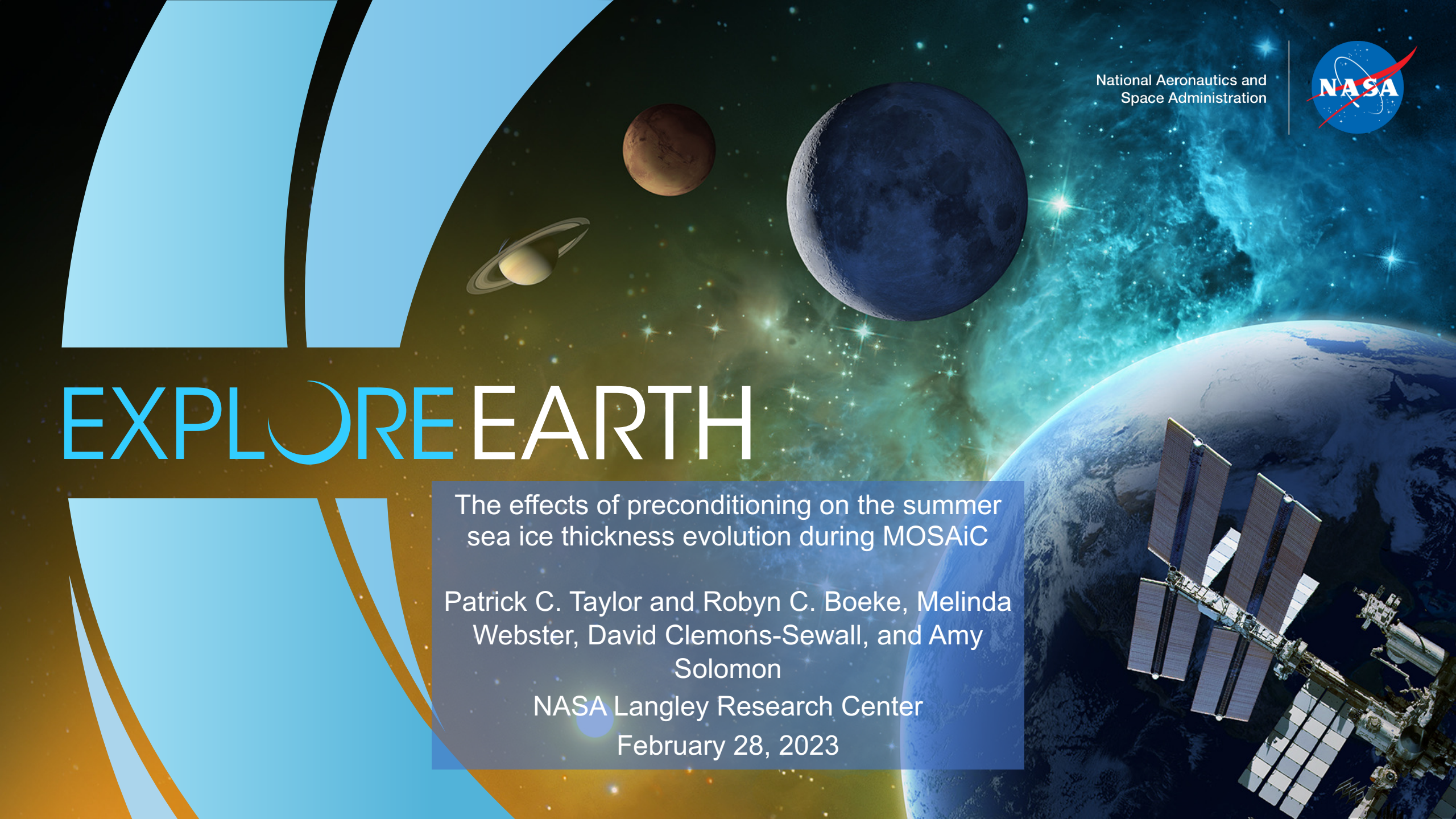


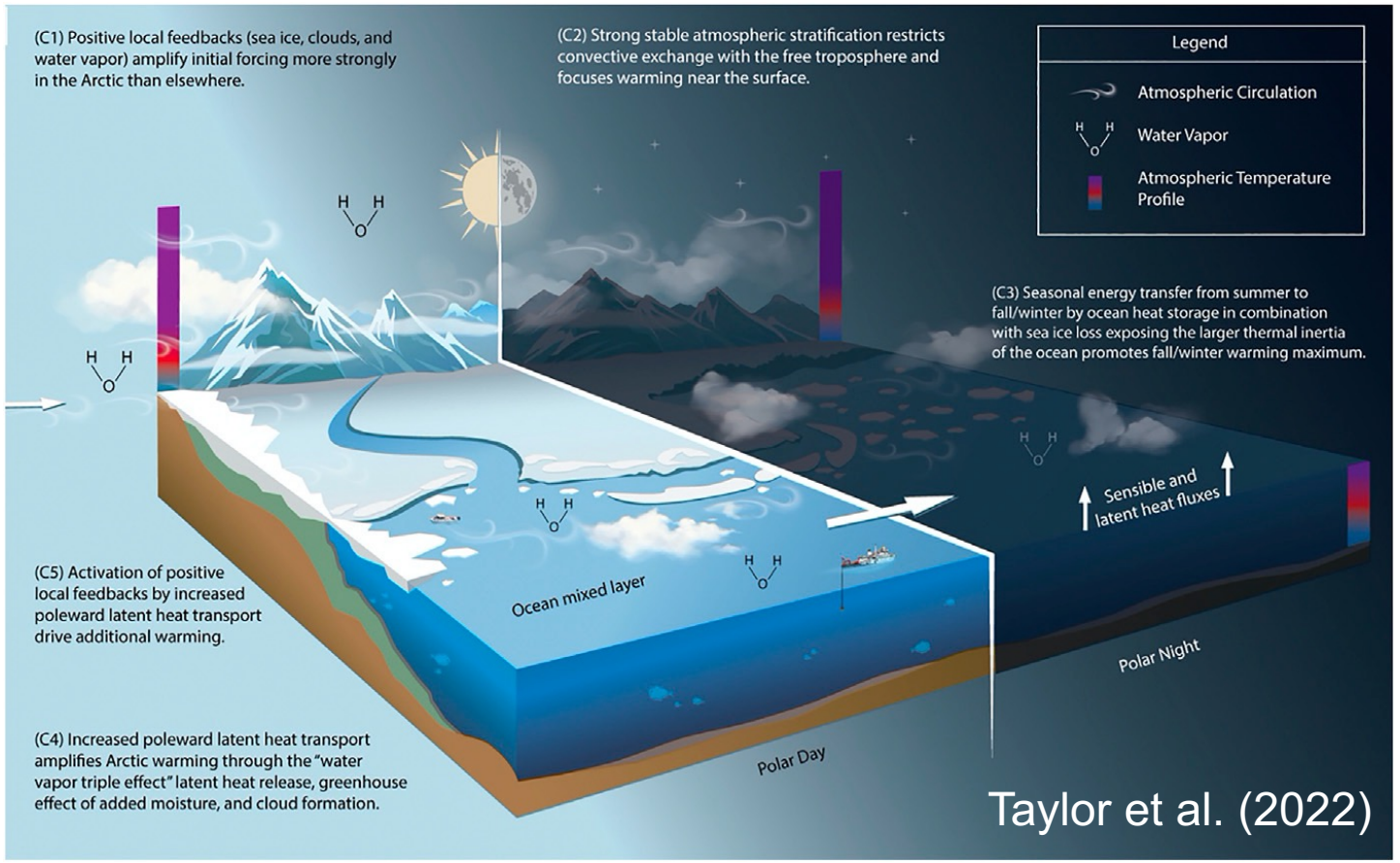
The effects of preconditioning on the summer sea ice thickness evolution during MOSAiC

Patrick C. Taylor and Robyn C. Boeke, Melinda Webster, David Clemons-Sewall, and Amy Solomon

NASA Langley Research Center

February 28, 2023

Conceptual Model of Arctic Amplification



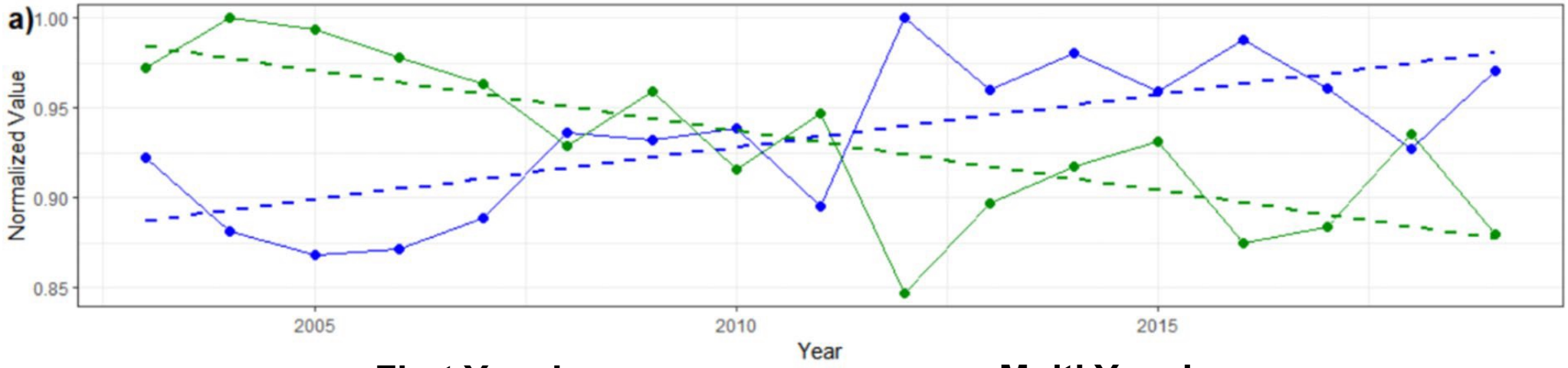
The conceptual model highlights the **need to account for local feedback and remote process interactions** within the context of the annual cycle to constrain the high-end of model projections.

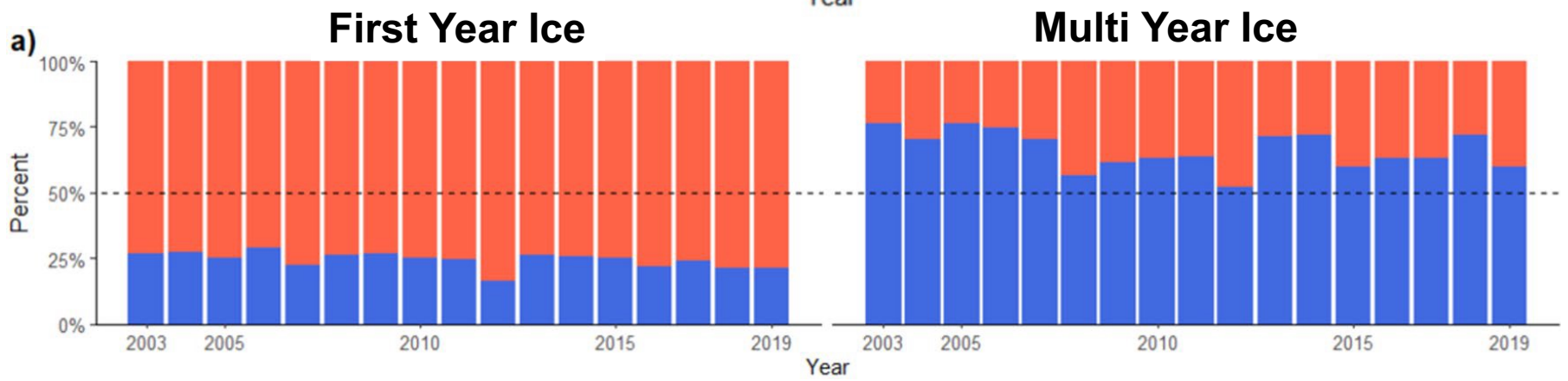
- Reducing uncertainty requires the understanding of the factors that influence sea ice survival within the context of the annual cycle.

Inter-annual variability of sea ice parcels

Green: normalized duration
Blue: normalized total parcels

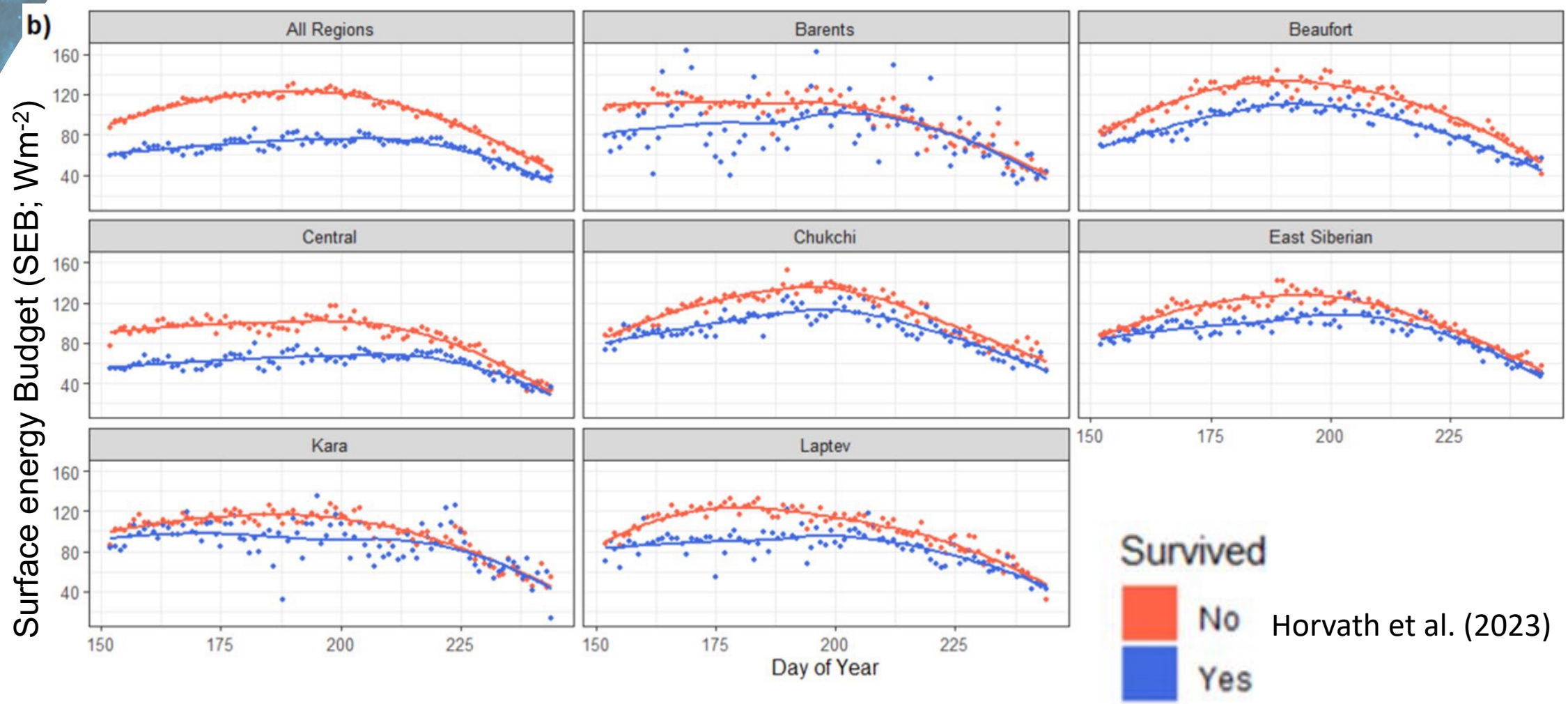
Increasing trend in the number of sea ice parcels and deceasing trend in parcel duration.





Greater inter-annual variability in the survival rate of Multi-year vs. First year sea ice.

Net surface energy budget and sea ice parcel survivability



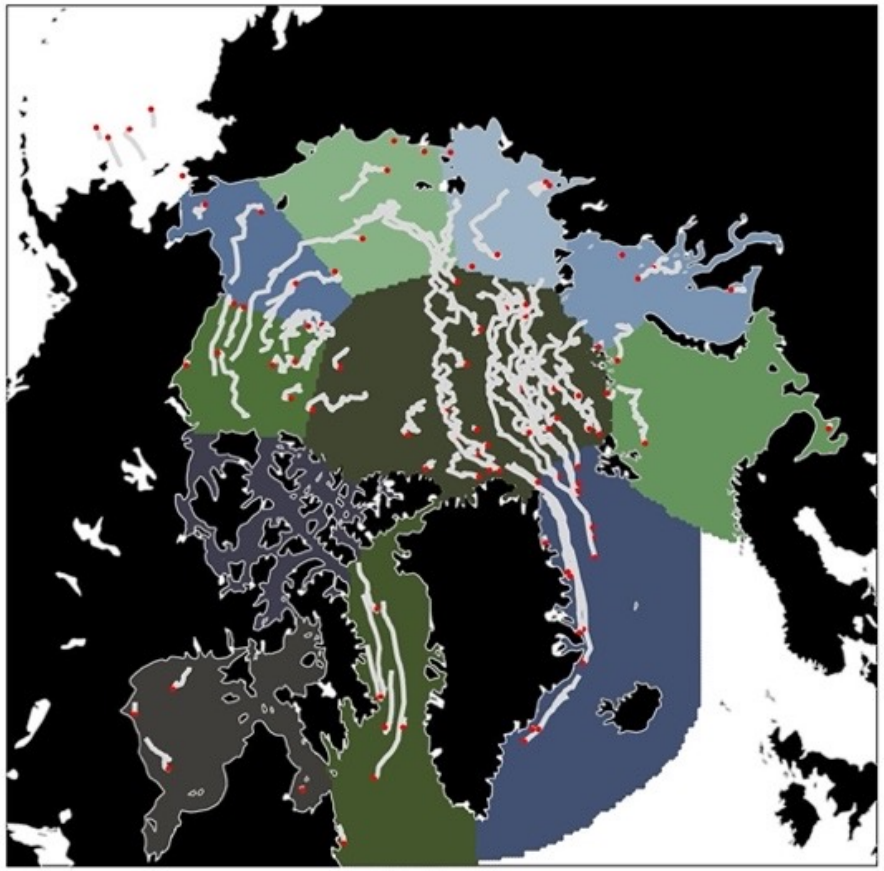
Horvath et al. (2023)

- Sea ice parcels that melt-out have a more positive net surface energy budget (greater energy input) than survived parcels.
- We find substantial regional differences in the timing of the SEB differences.

Overarching question:

How important are sea ice parcel history and pre-melt onset conditions to the summer thickness evolution?

Arctic sea ice parcel database: >1,000,000 parcels from 2002-2020

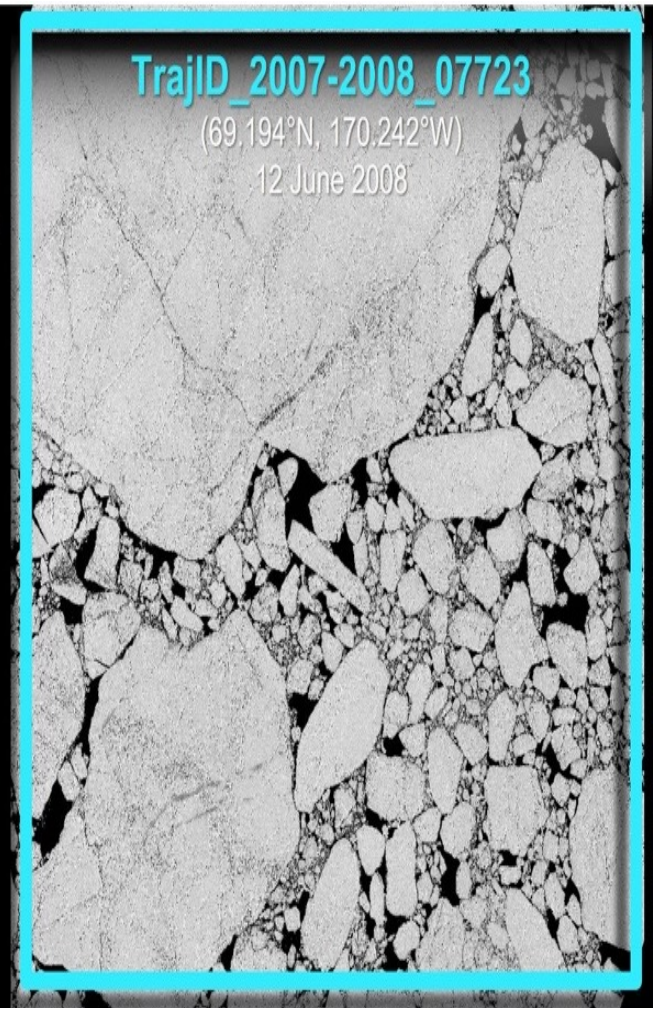


Sea Ice Characteristics:
Ice Type (Buoys/SSM/I): First Year
Concentration (NSIDC/CDR): 90%
Snow Depth (SnowModelLG): 0.06 m
Sea Ice Thickness (PIOMAS): 2.10 m
Surface Albedo (CERES): 0.50
Ice Surface Temperature:

Lifecycle:
Formation: 22 Nov. 2007
Duration: 211 days
End: 20 June 2008
Origin & End Region: Chukchi Sea
Survived: No

Flags:
Cyclone (Melbourne U. Tracker): n/a
Cyclone properties (ERA5): n/a

(Horvath et al. 2023)

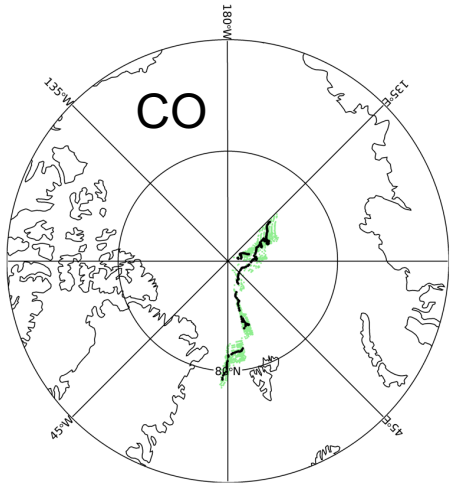


Atmospheric State:
Air Press. (ERA5/MERRA2): 1018 hPa
Cloud Cover (CERES): 15%
Precipitable Water (ERA5/MERRA2): 19 kg m^{-2}
Liq. Water Path (CERES): 112 g m^{-2}
Ice Water Path (CERES): 96 g m^{-2}
Air T.(ERA5/MERRA2): 0.95°C
Wind Speed & Direction (ERA5/MERRA2): 8.4 $m\text{-}s^{-1}$ & 39°
Spec. Humidity (ERA5/MERRA2): ~0%
Snowfall (ERA5/MERRA2): n/a
Total Precipitation (ERA5/MERRA2): n/a

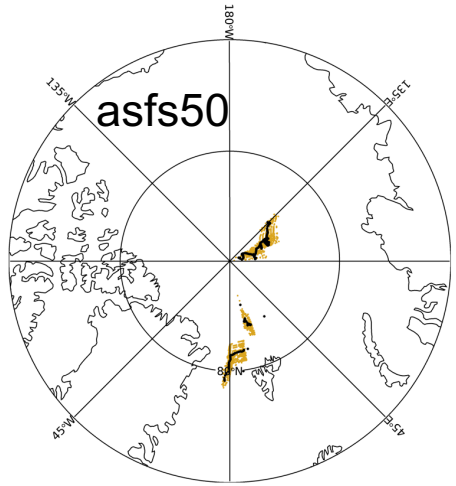
Surface Energy Budget:
Upwelling SW (CERES): 134 W m^{-2}
Downwelling SW (CERES): 267 W m^{-2}
Upwelling LW (CERES):312 W m^{-2}
Downwelling LW (CERES): 284 W m^{-2}
Sensible Heat (AIRS): -30 W m^{-2}
Latent Heat (AIRS): ~0 W m^{-2}

- New database enables novel studies on the factors influencing on sea ice parcel survival.

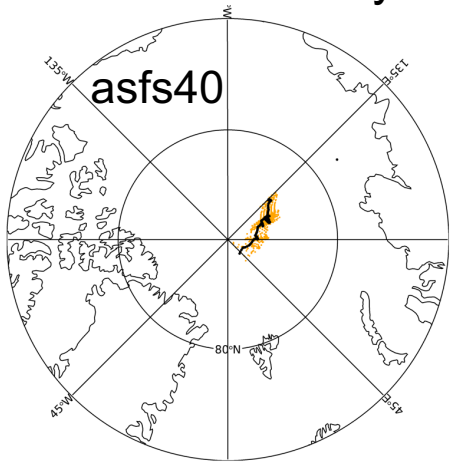
MOSAiC Station data collocated with IDS sea ice parcels



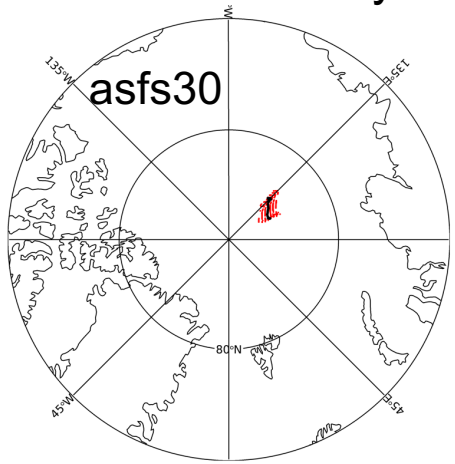
270 matched days



255 matched days



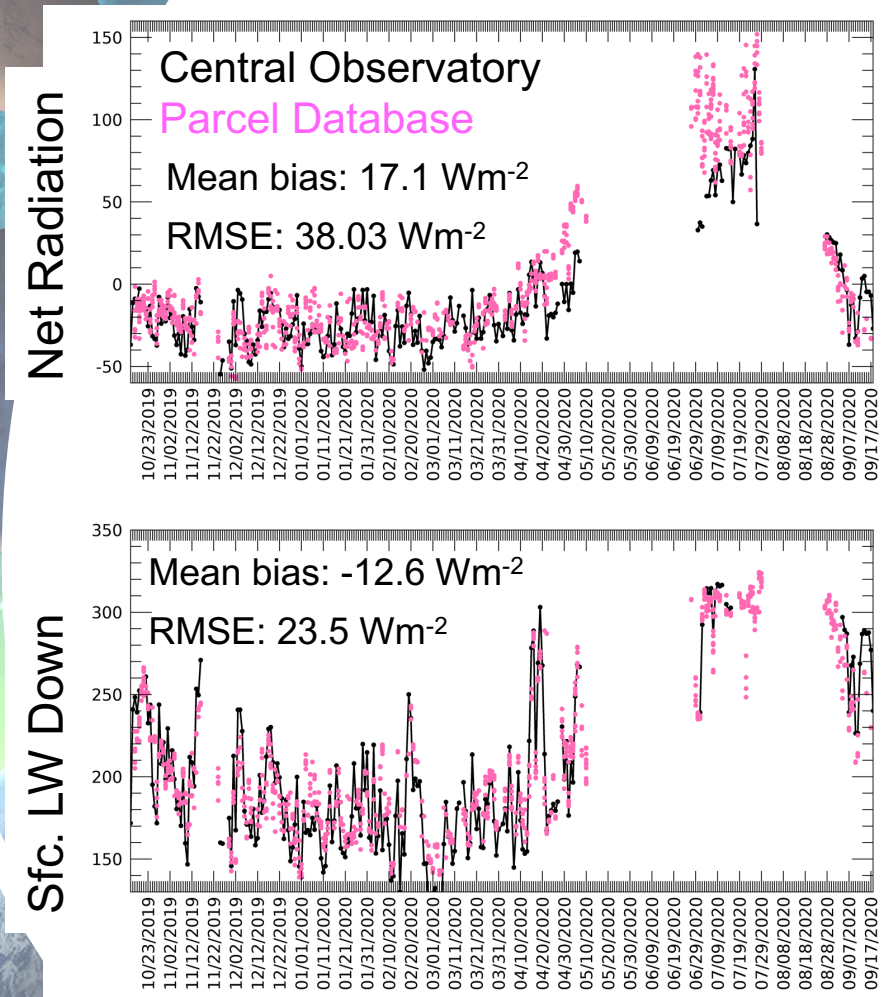
139 matched days

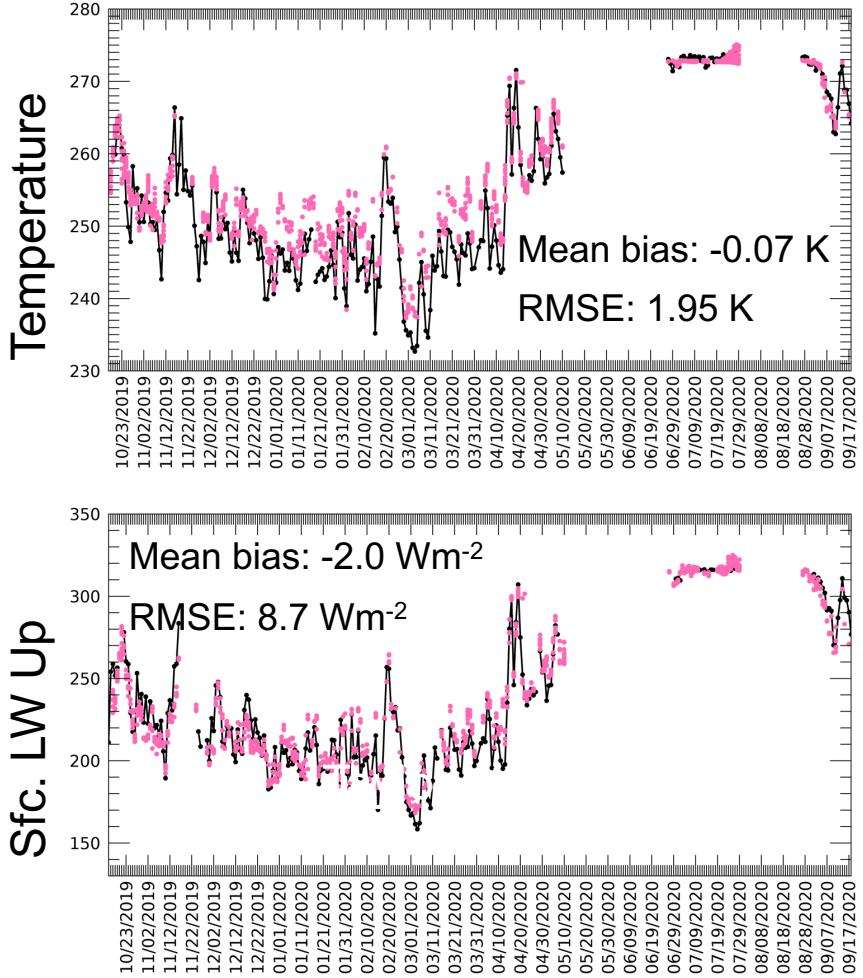


34 matched days

- Matching condition: same day, within 1deg (MOSAiC data averaged into daily averages)
- Each MOSAiC data point (each day) has up to 22 IDS sea ice parcels matched

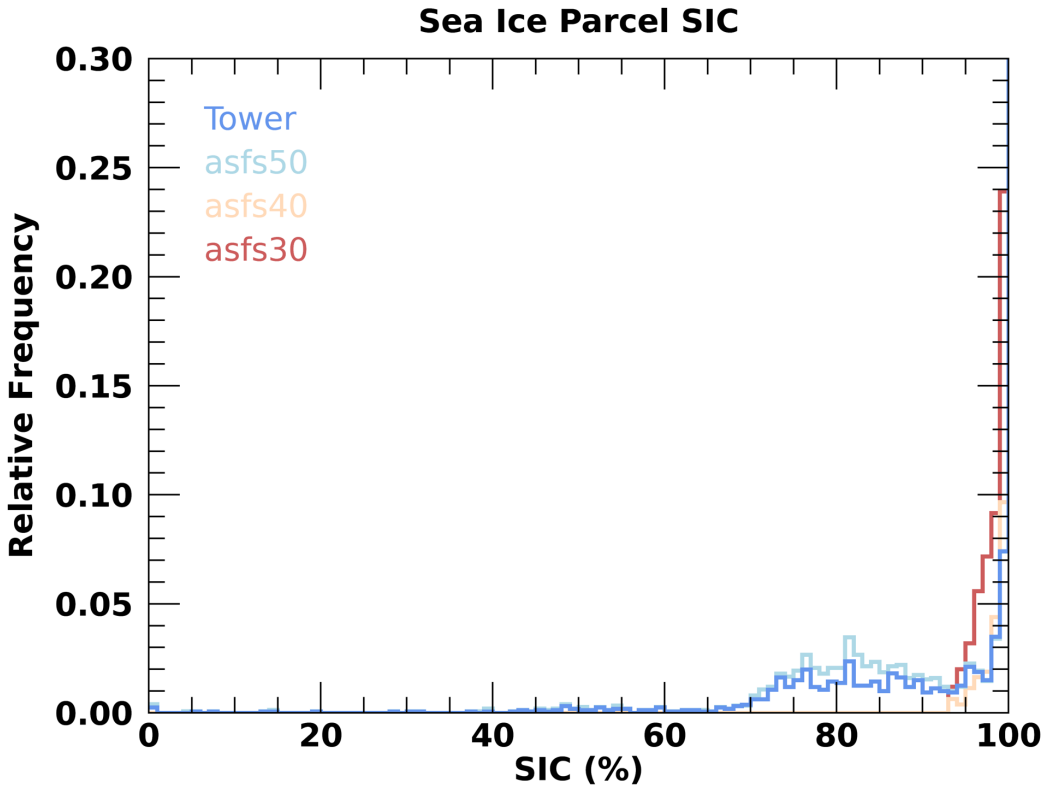
Evaluating Sea ice parcel products against MOSAiC in situ data

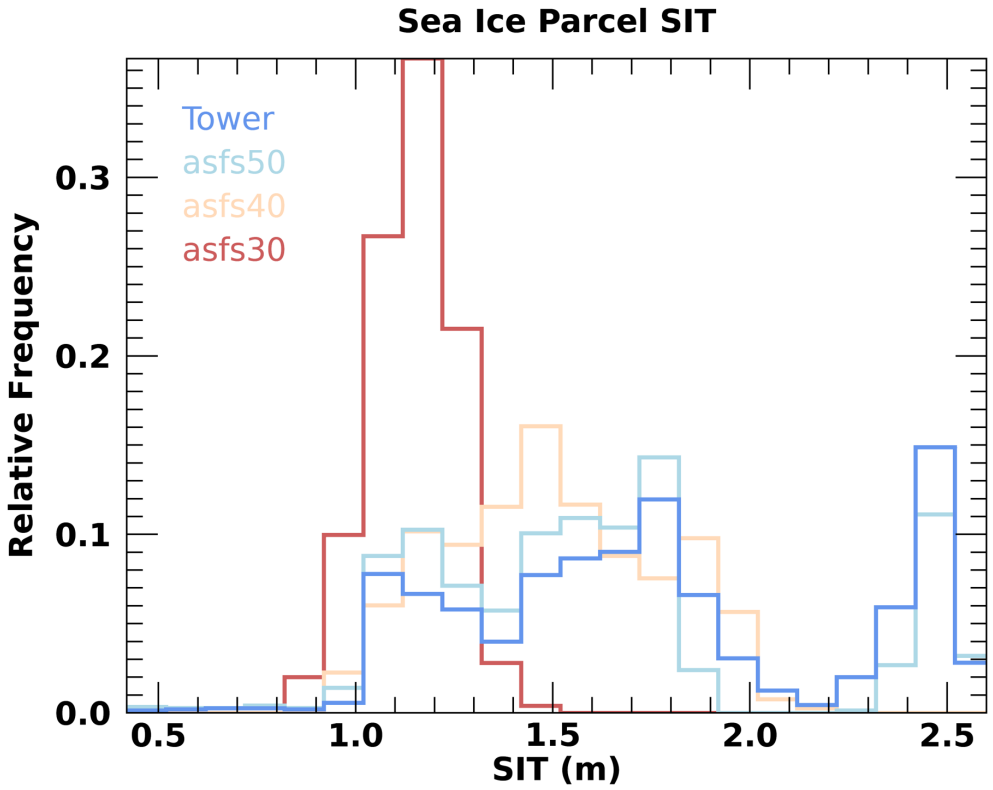




Surface temperature and LW radiative fluxes and from the sea ice parcel database agree well with MOSAiC in situ observations providing confidence in the

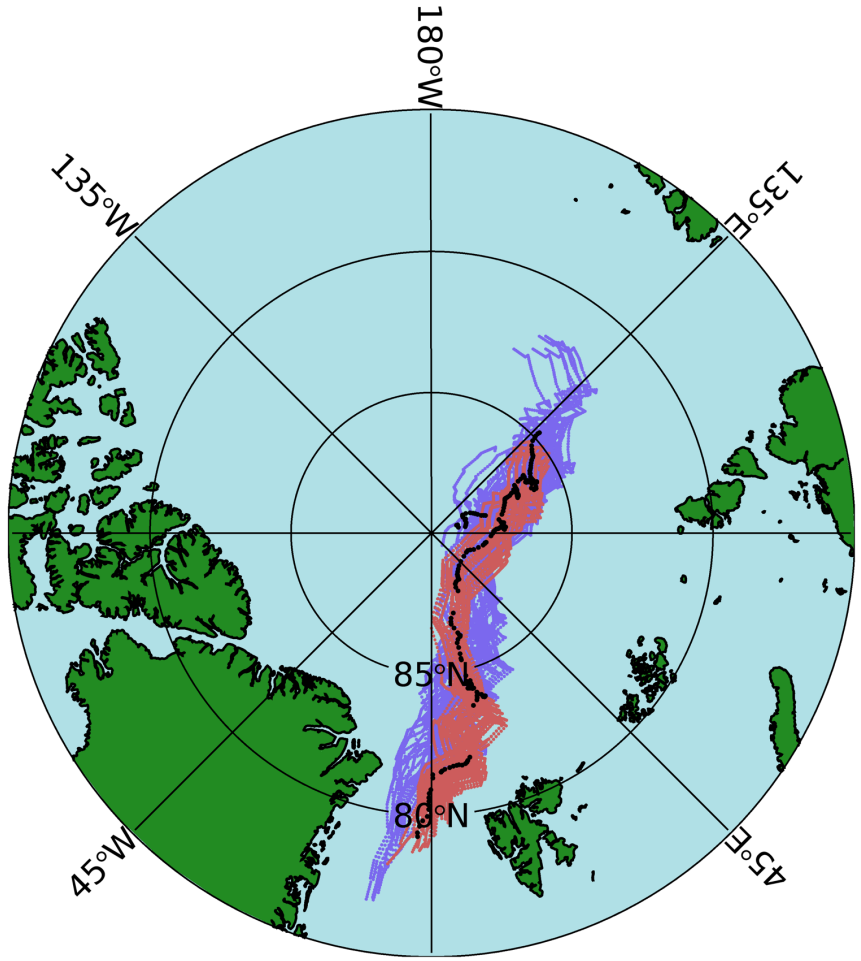
Sea ice parcel properties along the MOSAiC drift track





Sea ice parcel thicknesses ranged from ~0.5 to >2.5 m and sea ice concentration generally exceeded 70%.

Full drift tracks for matched parcels



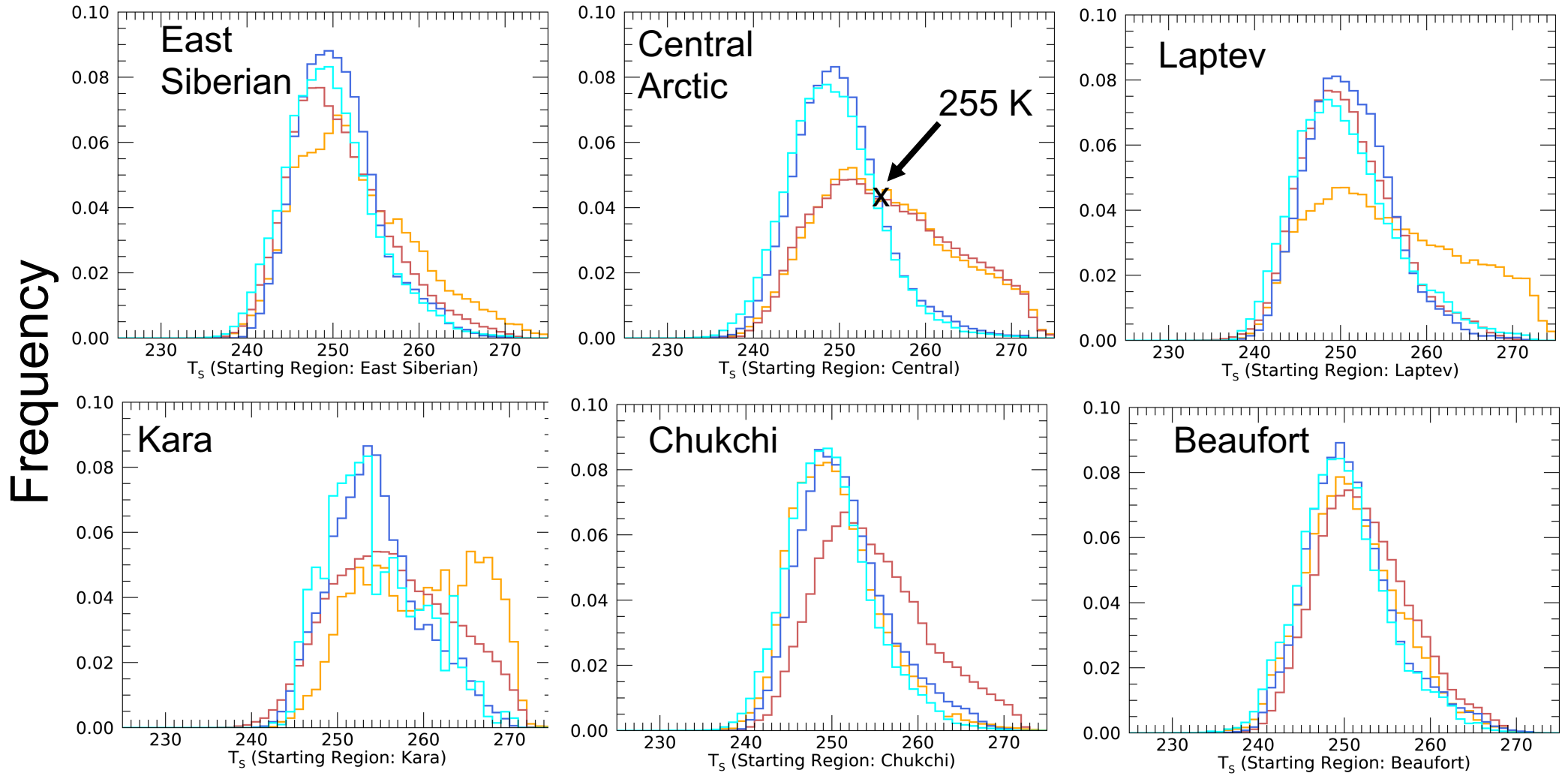
>500 sea ice parcels were matched with the drift track.

- Melted parcels in Red
- Survived Parcels in Purple
- Survived parcels followed a slightly different track than the drift track.
  - Started deeper into the Russian Arctic (further from the Fram Strait)
  - Veered eastward near 87N
  - Remained close to the Greenland coast.

Matched parcel generally follow the MOSAiC drift and provide a spatial context of the track.

Winter surface temp. distribution by region

Dark blue: FYI survived Cyan: MYI survived Red: FYI melted Orange: MYI melted

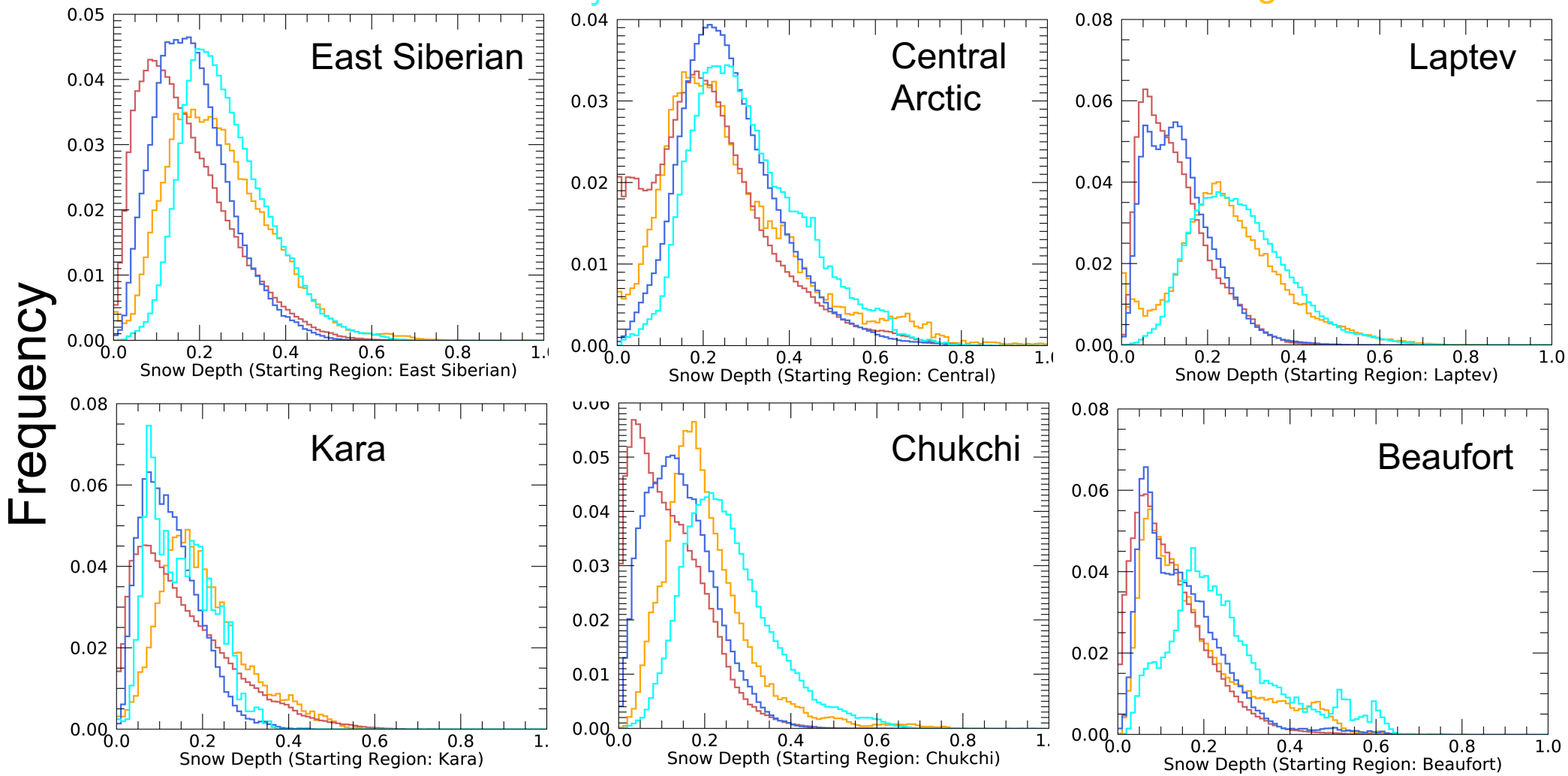


Parcels that experience **surface temperature >255 K** are less like to survive.

- Parcels that melt tend to experience warming winter surface temperatures.
- There is a strong regional variability in the influence of winter surface temperature.

Snow Depth distribution by region

Dark blue: FYI survived Cyan: MYI survived Red: FYI melted Orange: MYI melted

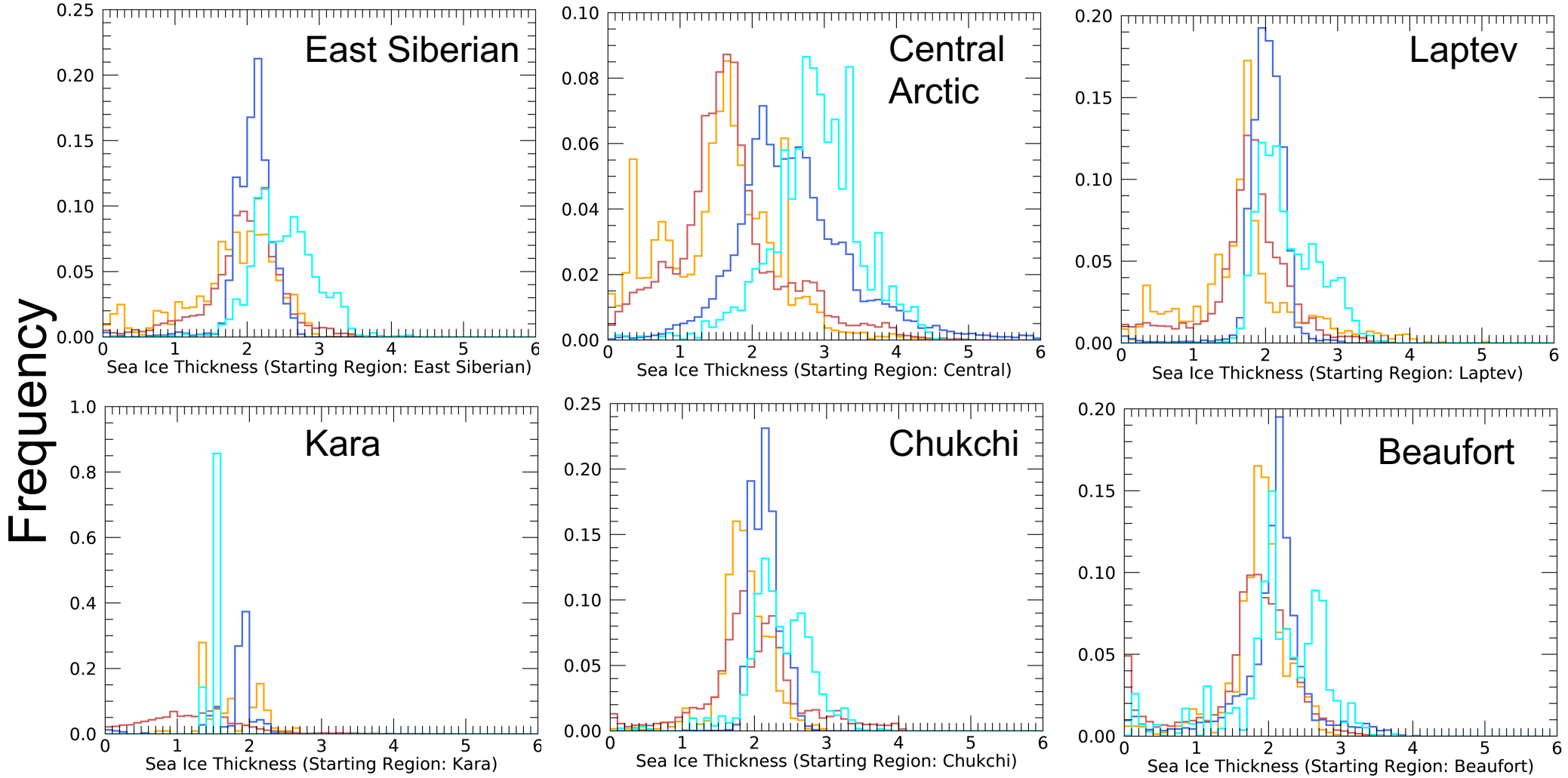


For survival, more snow is better.

- Snow depth at melt onset (not shown) indicates a weak influence on sea ice parcel survival that is consistent across regions.
- More winter (Nov-Mar) snow depth contributes to a greater survival (regionally varying).

Sea ice thickness at melt onset by region

Dark blue: FYI survived Cyan: MYI survived Red: FYI melted Orange: MYI melted

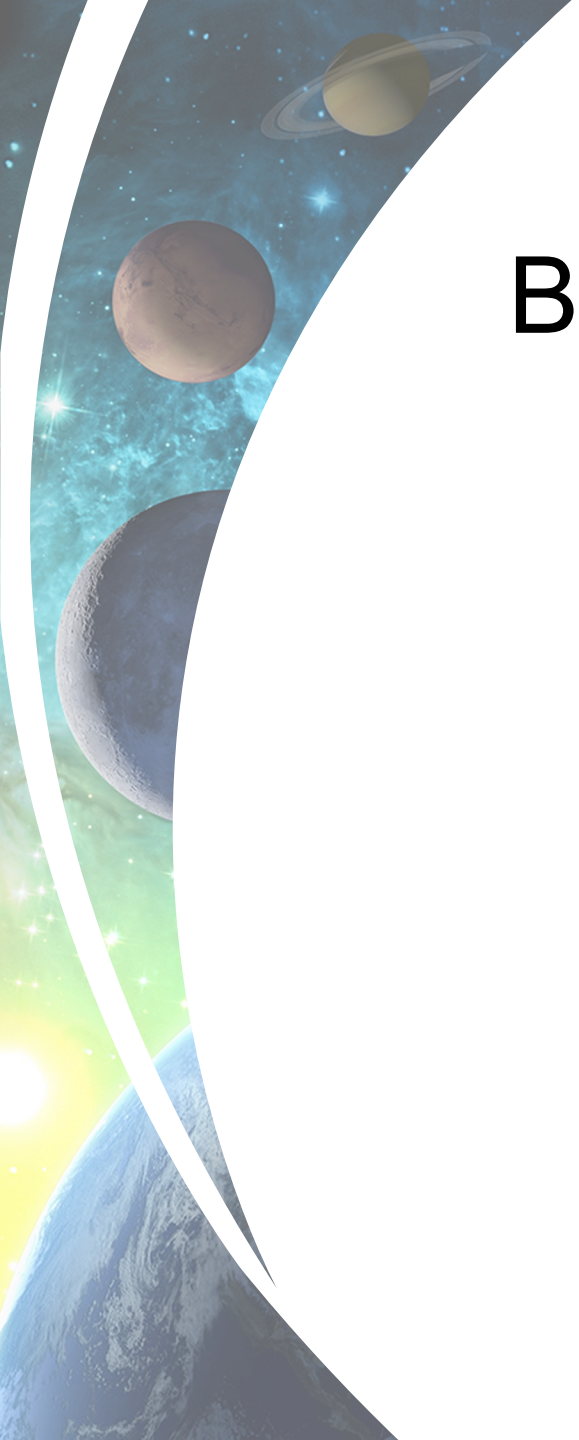


Parcels **<2 m** thick have a low summer survival rate.

- Tendency for thinner sea ice at melt onset to melt and thicker sea ice to survive.
- The PDFs show a strong regional variability in the importance of thickness.

Summary and Takeaways:

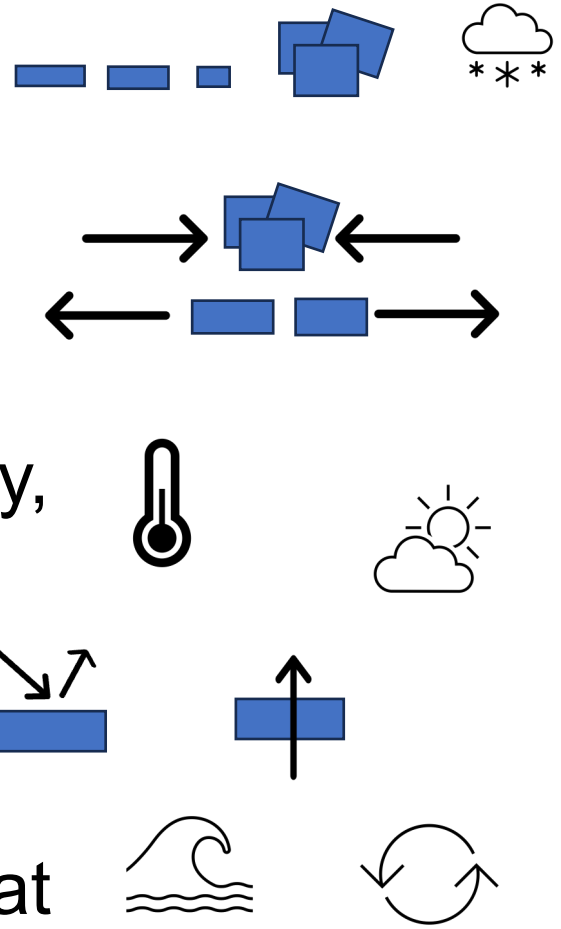
- The LaGrangian database enables the analysis of the factors that influence the evolution of sea ice parcels as they move around the Arctic (Horvath et al. 2023; https://doi.org/10.5281/zenodo.7554521).
- Sea ice parcel database (comprised on satellite and reanalysis datasets) shows good agreement with the matched in situ MOSAiC observations.
- Results indicate…
  - Pre-melt onset snow cover and winter surface temperature influence summer sea ice thickness evolution.
  - Cloud play exhibit an influence on the role on the pre-melt onset thickness and summer evolution.
  - The drift sea ice parcel drift speed influences parcel survival.
  - The influence of pre-melt onset conditions is sensitive to the sea ice parcel thickness.



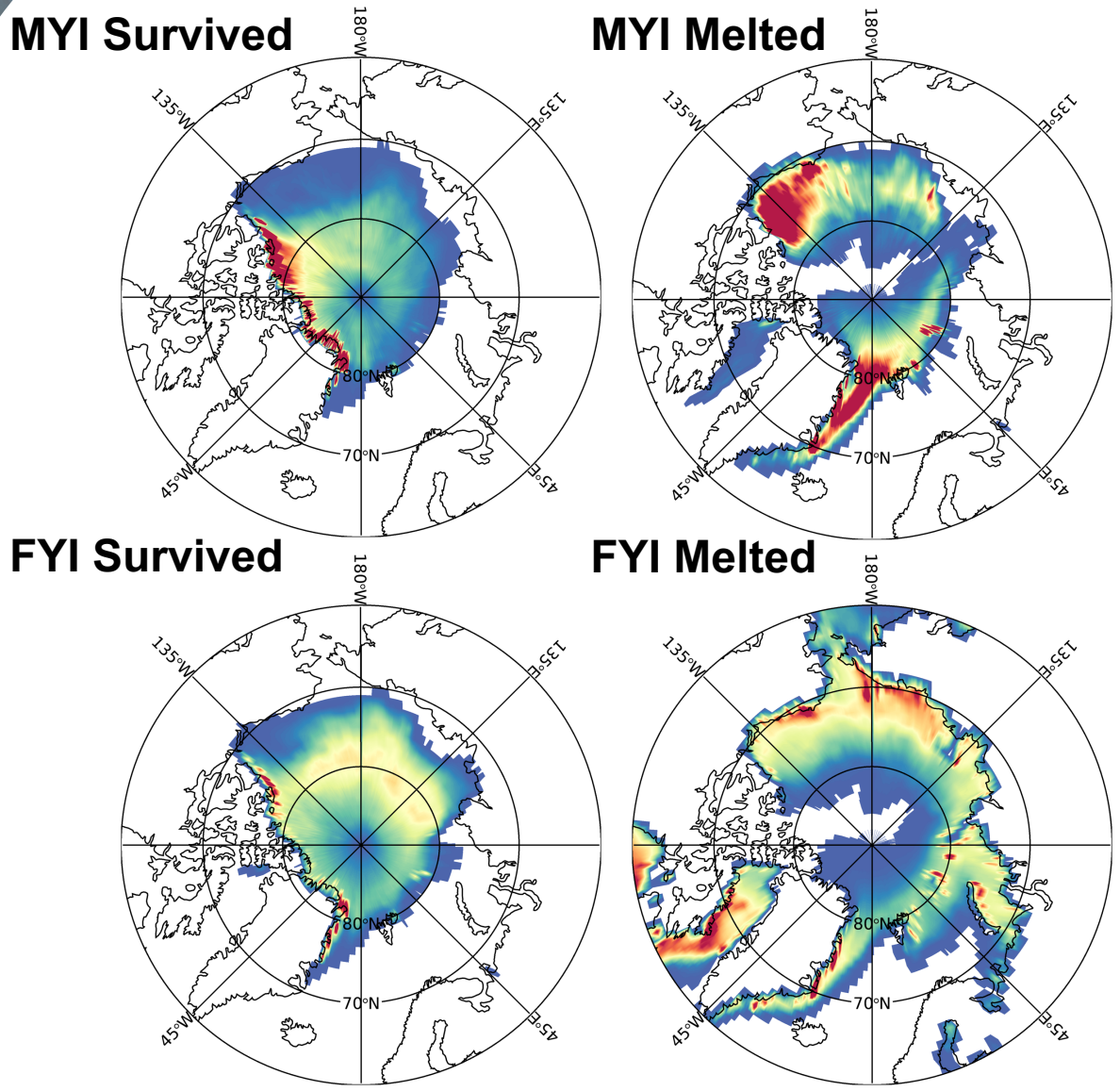
Back-up Slides

Some factors that influence sea ice survivability

- Sea ice properties (thickness, concentration, topography/roughness, snow depth)
- Sea ice dynamics (convergence and divergence)
- Atmospheric conditions (temperature, humidity, clouds)
- Surface energy budget (turbulent fluxes, conductance, albedo)
- Ocean conditions (waves, turbulence, and heat flux)



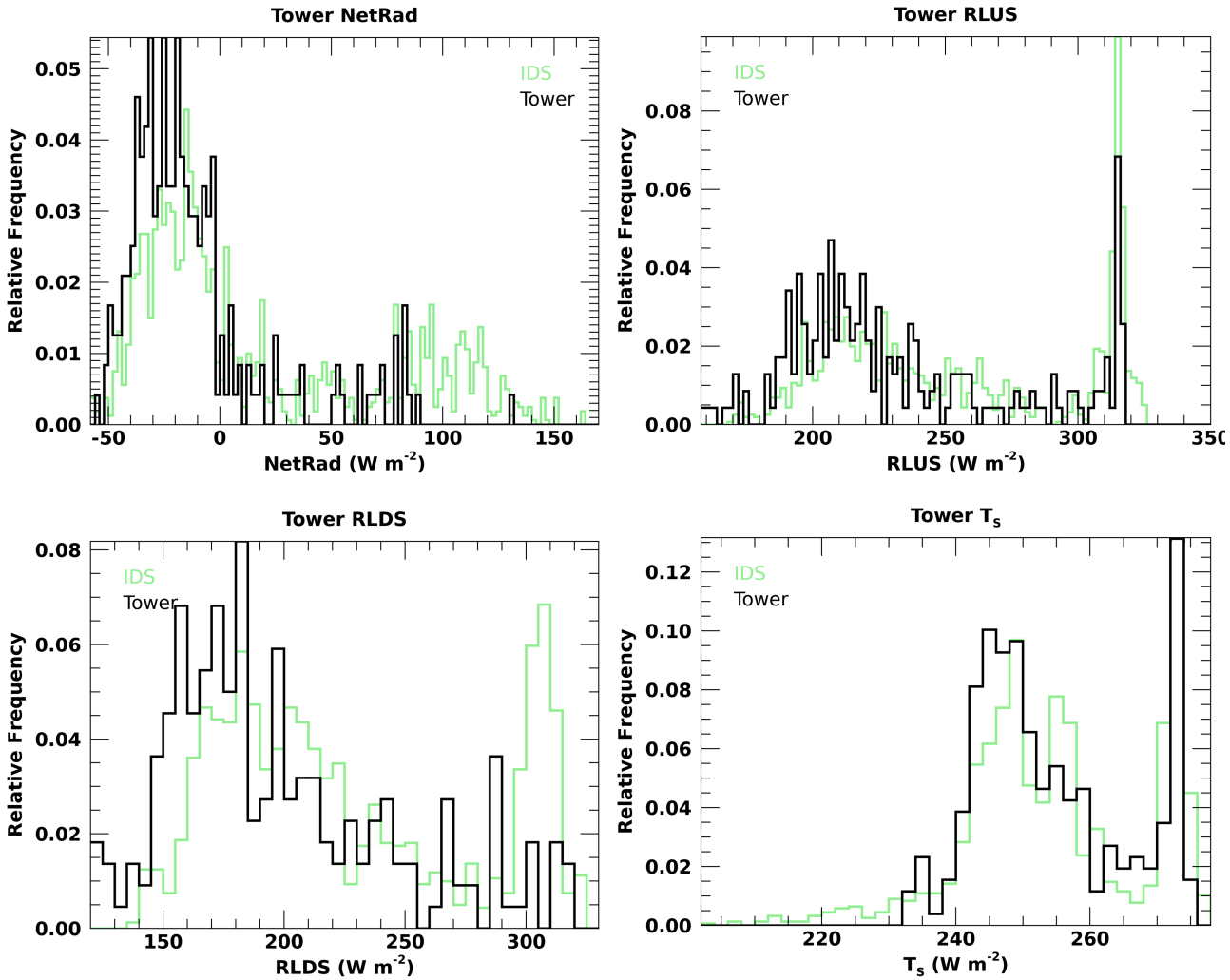
Sea ice havens, graveyards, and nurseries



- **Sea ice Havens:**
  - Central Arctic
  - North of Greenland and the Canadian Archipelago
- **Sea ice Graveyards:**
  - Fram Strait
  - Peripheral Seas
- **MYI Nursery**
  - Central Arctic.

- **FYI survives when it moves towards the central Arctic.**
- **MYI melts out when it is advected into the Fram Strait and Beaufort Sea.**

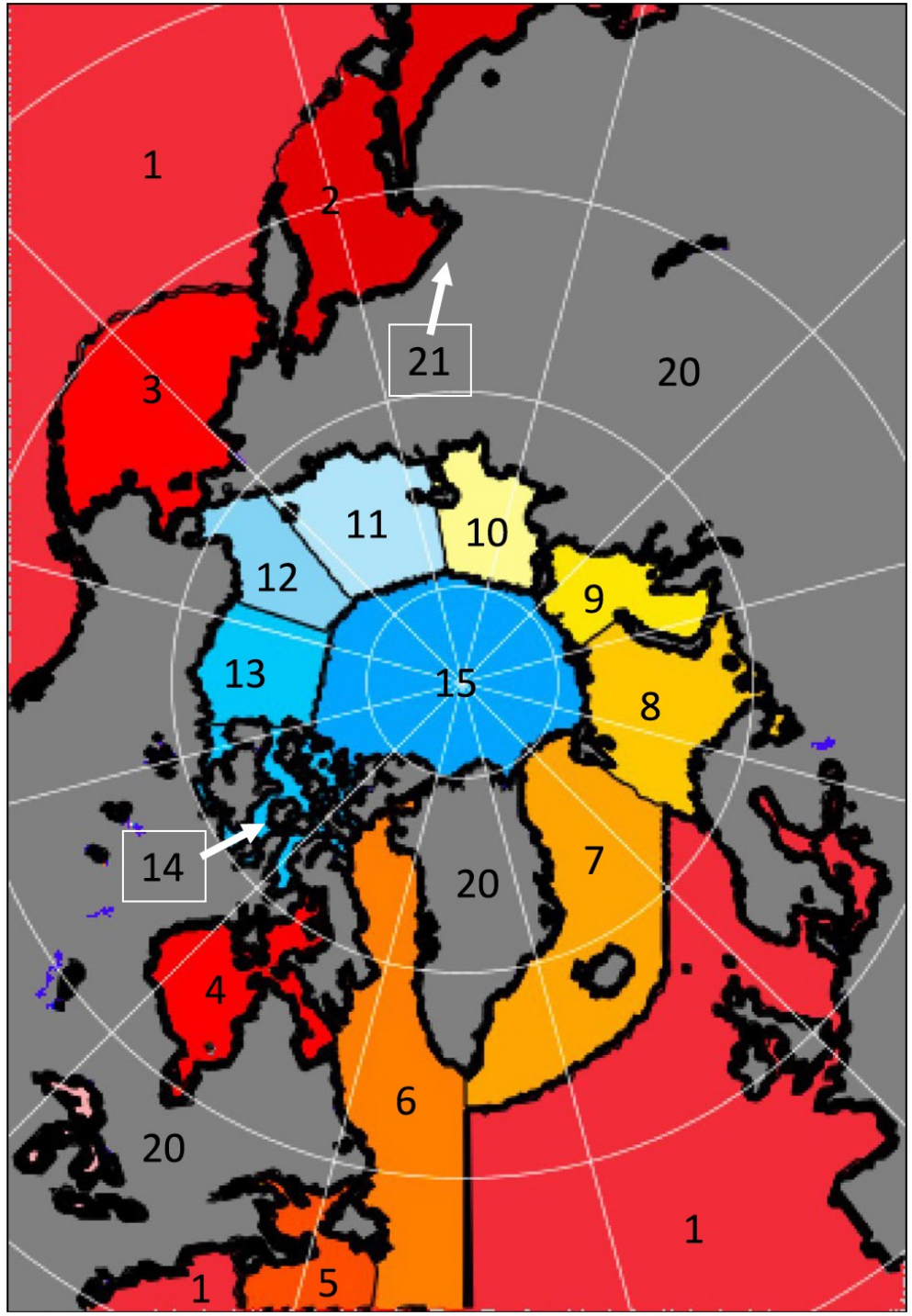
Evaluating Sea ice parcel data products against MOSAiC: PDFs



Surface temperature and LW radiative fluxes and from the sea ice parcel database agree well with MOSAiC in situ observations.

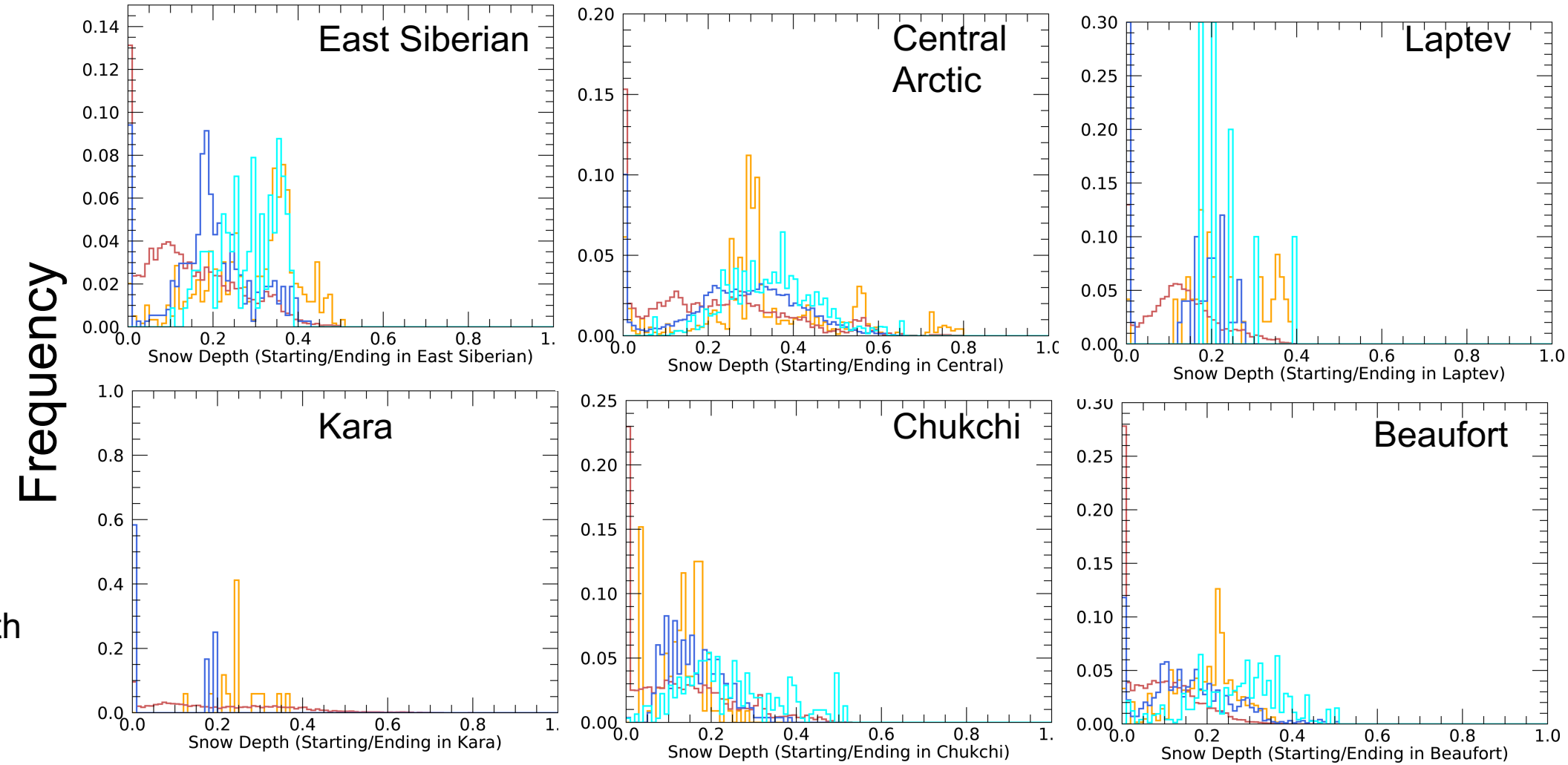
Region Definitions

1: Open Ocean
2: Sea of Okhotsk
3: Bering Sea
4: Hudson Bay
5: North Atlantic
6: Baffin Bay/Labrador Sea
7: E. Greenland Sea
8: Barents Sea
9: Kara Sea
10: Laptev Sea
11: E. Siberian Sea
12: Chukchi Sea
13: Beaufort Sea
14: Canadian Archipelago
15: Central Arctic,



Snow depth distributions at melt onset end region:

Dark blue: FYI survived Cyan: MYI survived Red: FYI melted Orange: MYI melted

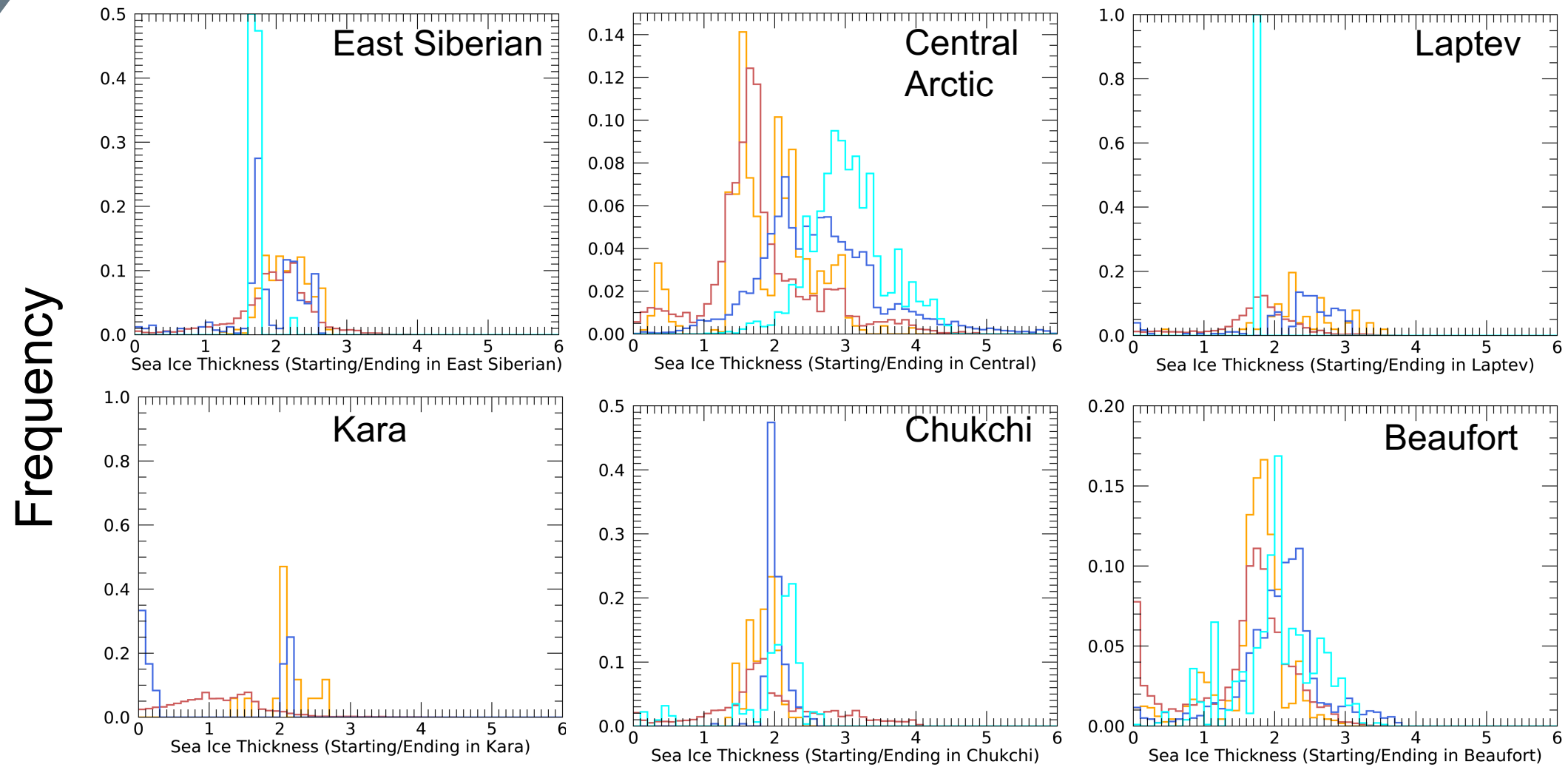


No clear snow depth threshold.

- Snow depth at melt onset shows a weak influence on sea ice parcel survival that is consistent across regions.
- The influence of snow depth could still be a substantial factor in preconditioning.

Sea ice thickness distributions by start/end region

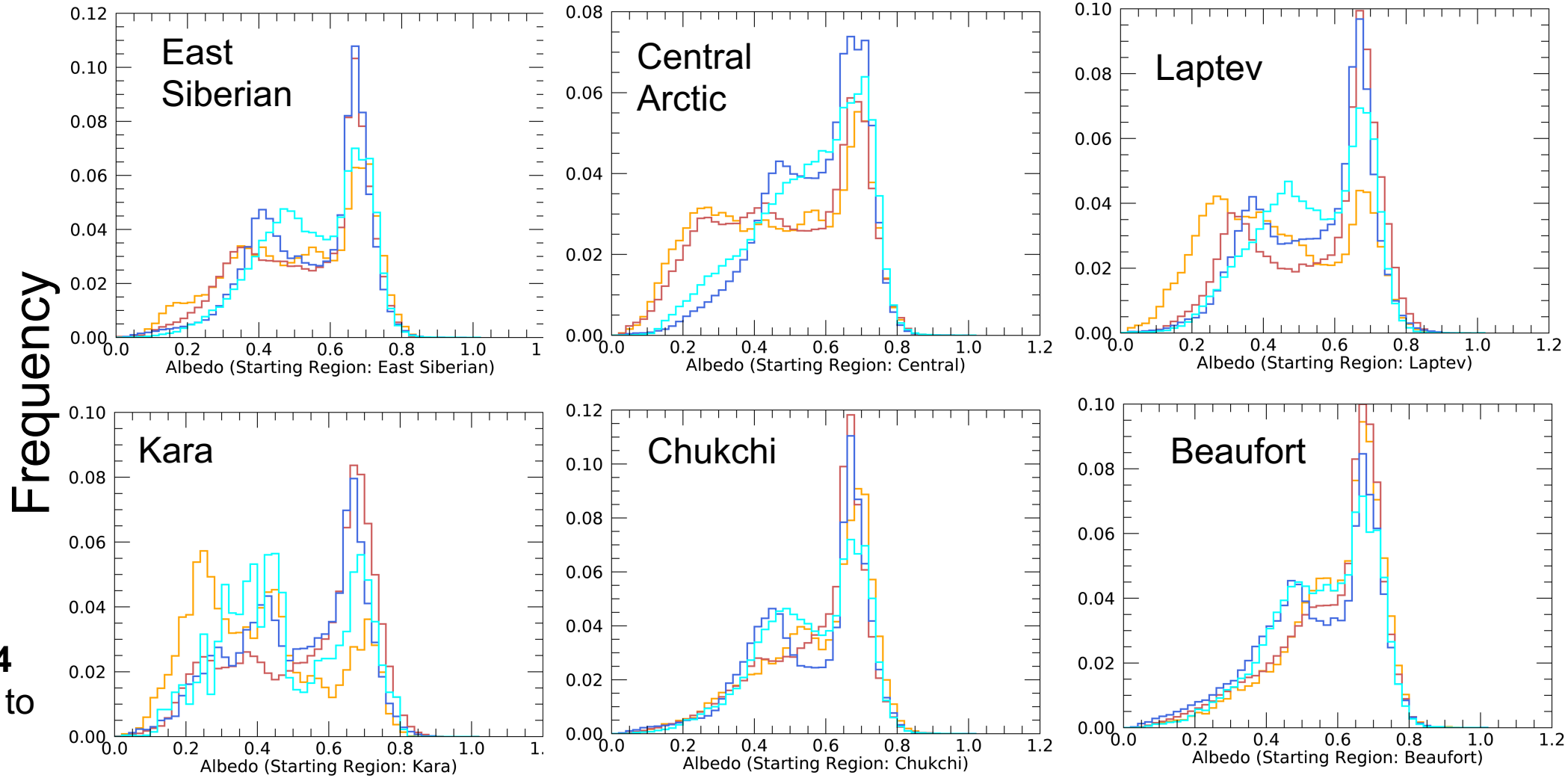
Dark blue: FYI survived Cyan: MYI survived Red: FYI melted Orange: MYI melted



- Tendency for thinner sea ice at melt onset to melt and thicker sea ice to survive; a strong regional variability.

Surface albedo distribution by region

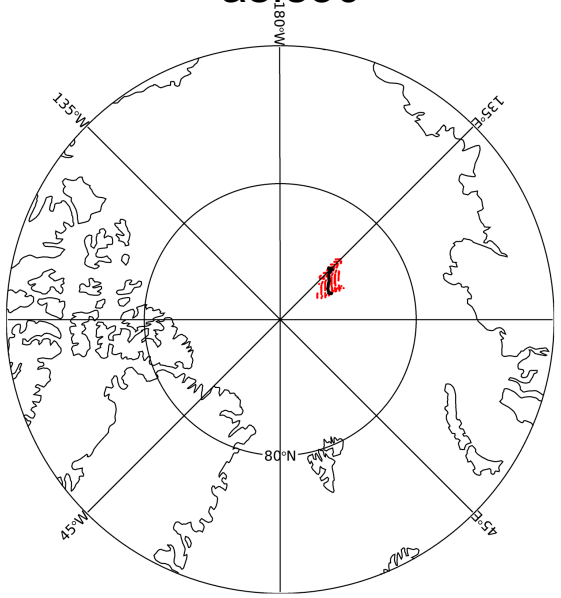
Dark blue: FYI survived Cyan: MYI survived Red: FYI melted Orange: MYI melted



Parcels that with surface **albedo < 0.4** are less like to survive.

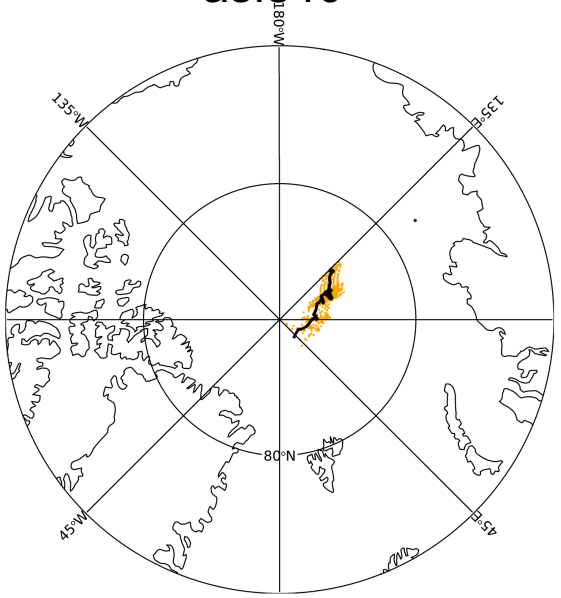
- Parcels the melt-out tend to have a lower surface albedo than parcels survive.
- A strong regional variability is found with melted parcels showing a more rapid summer decline in surface albedo than survived parcels.

asfs30



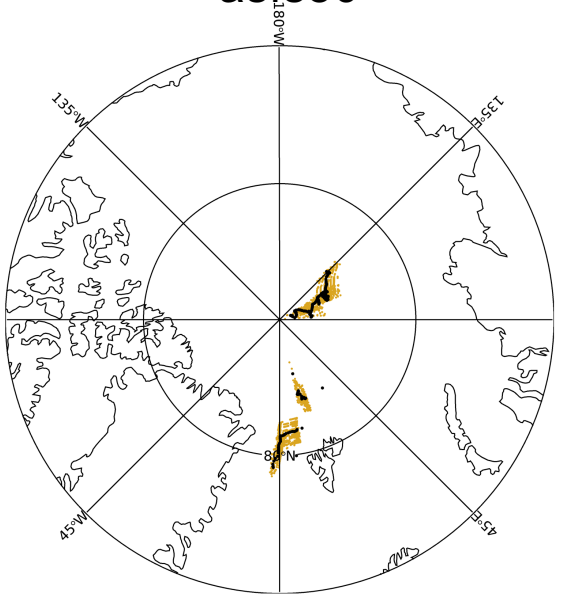
- 34 days of matched data
- 79.2% of sea ice parcels survived
- avg sea ice parcel lifespan: 349.5 days
- All parcels originated in Central; all ended in either Central or East Greenland

asfs40



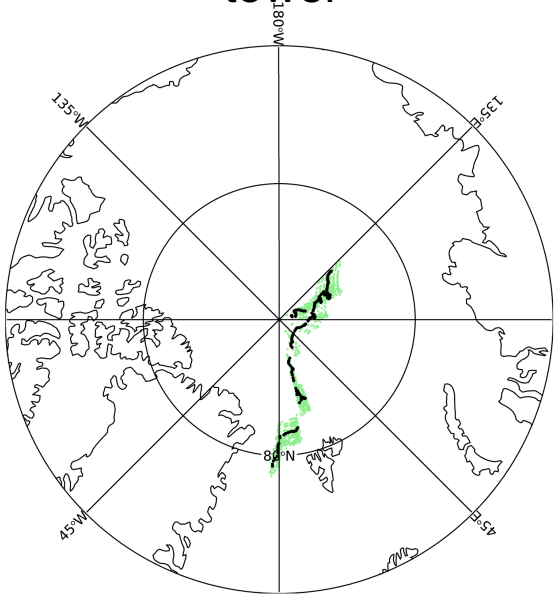
- 139 days of matched data
- 80.9% of sea ice parcels survived
- avg sea ice parcel lifespan: 343 days
- All parcels originated in Central; all ended in either Central or East Greenland

asfs50



- 255 days of matched data
- 50.5% of sea ice parcels survived
- avg sea ice parcel lifespan: 261.2 days
- Most parcels originated in Central, some in E. Greenland, 1 in E. Siberian. Ended in E. Greenland/Central.

tower



- 270 days of matched data
- 56.7% of sea ice parcels survived
- avg sea ice parcel lifespan: 274.8 days
- Most parcels originated in Central, some in E. Greenland, 1 in E. Siberian. Ended in E. Greenland/Central.